CHARACTERISTICS OF THE AIRS VERSION 5 RETRIEVAL ALGORITHM

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OVERVIEW OF AIRS/AMSU RETRIEVAL METHODOLOGY

Physically based system

Independent of GCM except for surface pressure

Uses cloud cleared radiances $\hat{R}_i$ to produce solution

$\hat{R}_i$ represents what AIRS would have seen in the absence of clouds

Basic steps

- Initial cloud clearing produces $\hat{R}_i^0$
- AIRS regression guess parameters based on cloud cleared radiances $\hat{R}_i^0$
- Update cloud clearing using AIRS regression guess parameters: produces $\hat{R}_i$
- Sequentially determine surface parameters, T(p), q(p), O_3(p), CO(p), CH_4(p), using $\hat{R}_i$

Generate error estimates and apply quality control

Determine cloud parameters consistent with retrieved state and observed radiances

SIGNIFICANT IMPROVEMENTS IN AIRS VERSION 5.0 ALGORITHM

Physical retrieval algorithm

Improved radiative transfer parameterization accounts for Non Local Thermodynamic

Equilibrium (non-LTE) effects

Allows for use of many more shortwave temperature sounding channels

Most longwave temperature profile channels used only for cloud clearing

Shortwave temperature sounding channels used for temperature profile

Error estimates

New methodology developed to provide accurate case by case error estimates

Uses residuals of the physical retrieval and cloud clearing steps

Error estimates used directly for quality control

AIRS only cloud clearing/retrieval system Version 5.0 AO

Developed as a backup system in case AMSU A fails

CHANNELS AND FUNCTIONS USED IN V5.0

Temperature sounding channels

664 cm^{-1} - 713 cm^{-1}

2198 cm^{-1} - 2395 cm^{-1}

shortwave tropospheric temperature sounding channels only

Surface retrieval channels

2421 cm^{-1} - 2659 cm^{-1}

shortwave window channels only

Emissivity functions

1 SW ε function, LW emissivity remains at ε_{ν}^{reg}

1 ρ function

Cloud clearing

655 cm^{-1} - 812 cm^{-1}

longwave cloud clearing channels only

RATIONALE FOR VERSION 5 CHANNEL SET

- Theory says cloud clearing (determination of η) should be performed using only LW channels and $T(p), T_s$ determined from SW channels

  Errors in $T(p), T_s$ are less affected by errors in $T^n(p), T^n{}_s$ used to determine η^n

- T_s, ε_ν now determined only from channels near 2390 cm^{-1} used for lower tropospheric T(p)

  Scene surface non-homogeneity results in ν dependent effective values of T_s, ε_ν

  Surface non-homogeneity in actual T_s, ε_ν will result in less degradation in T(p)

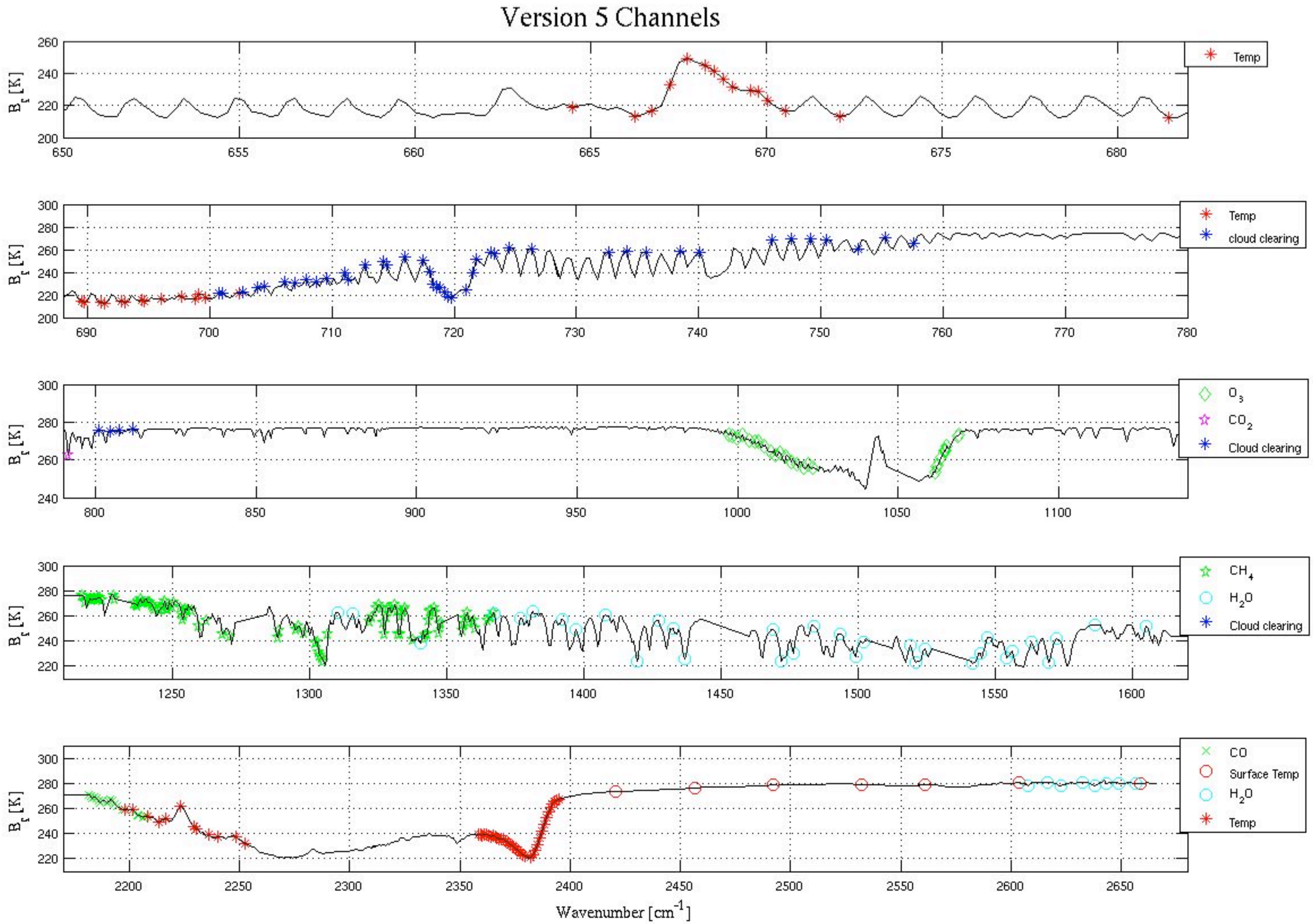
Plans for further improvement - Version 6

Determine $T_s, \varepsilon_{sw}, T(p)$ in a single step (no prior surface retrieval step)

Do surface parameter retrieval with LW window channels to determine ε_{LW}

(3 functions?)

Will help subsequent cloud clearing, q(p), O_3(p) retrievals



Version 5 Channels
B_f [K]
Temp
cloud clearing
O3
CO2
Cloud clearing
CH4
H2O
CO
Surface Temp
Wavenumber [cm^-1]

GENERATION OF EMPIRICAL ERROR ESTIMATES δX_i

This step is done after physical retrieval is otherwise completed

Methodology used for $\delta SST, \delta T(p)$ **is identical**

Uses 16 internally computed values of convergence tests Y_j

Thresholds of 12 Y_j terms are used in Version 4 quality control

δX_i, error estimate for X_i is computed according to

$$\delta X_i = \sum M_{ij} Y_j$$

Determination of M_{ij}

Use profiles with "truth"

$$\Delta X_i = \left| X_i - X_i^{TRUTH} \right|$$

Each profile now has $\Delta X_i, Y_j$

M_{ij} found which minimizes RMS $\left| \delta X_i - \Delta X_i \right|$

M_{ij} generated using all September 29, 2004 cases in which IR retrieval is accepted

ECMWF taken as "truth" to provide ΔX_i

M_{ij} tested on January 25, 2004

Same basic approach is used for $\delta \hat{R}_i, \delta q(p)$

METHODOLOGY USED FOR QUALITY CONTROL

Temperature Profile T(p)

Define a profile dependent pressure, p_g above which the temperature profile is flagged as good

Use error estimate $\delta T(p)$ to determine p_g

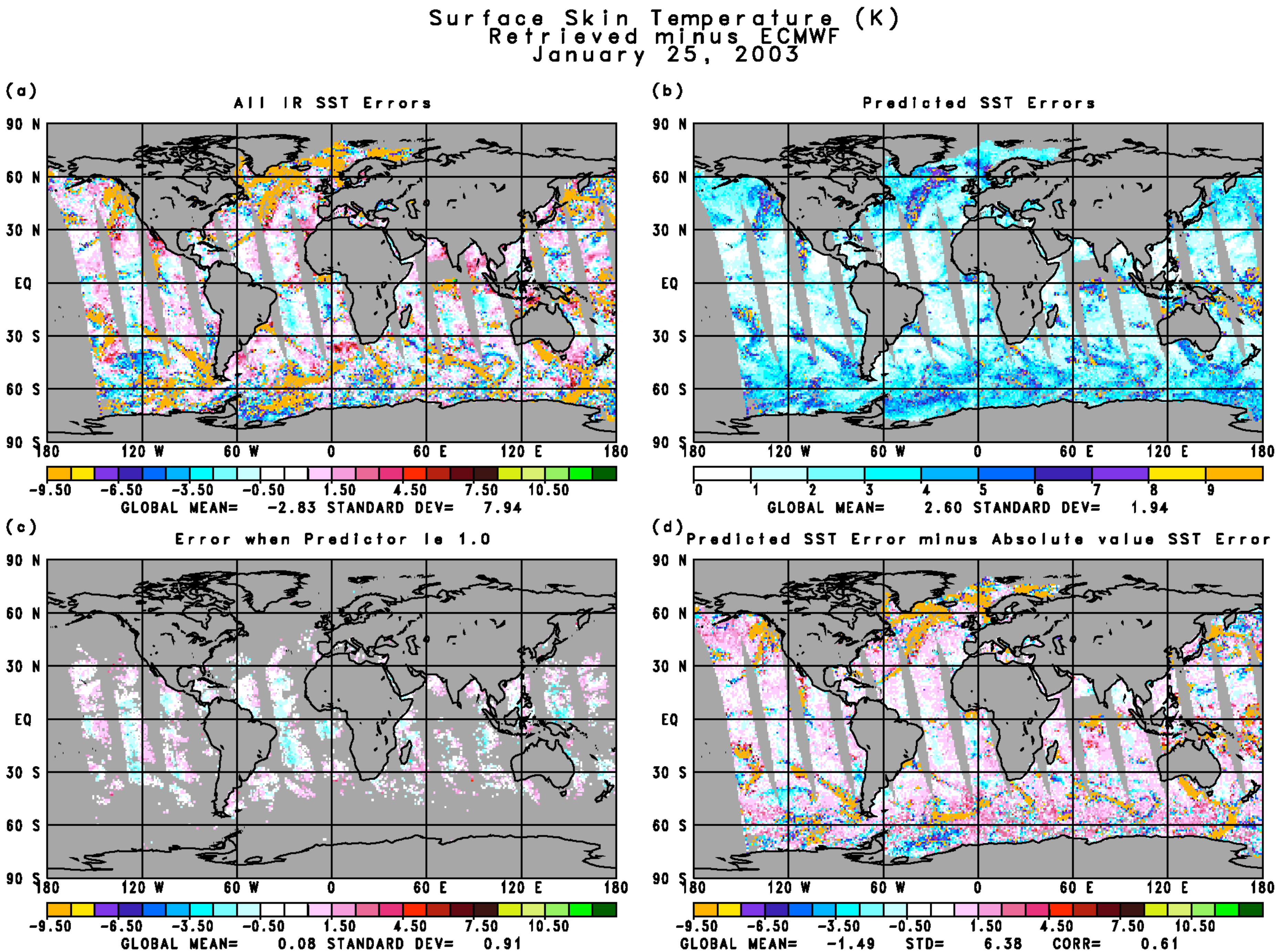
Start from 70 mb and set p_g to be the pressure at the first level below which

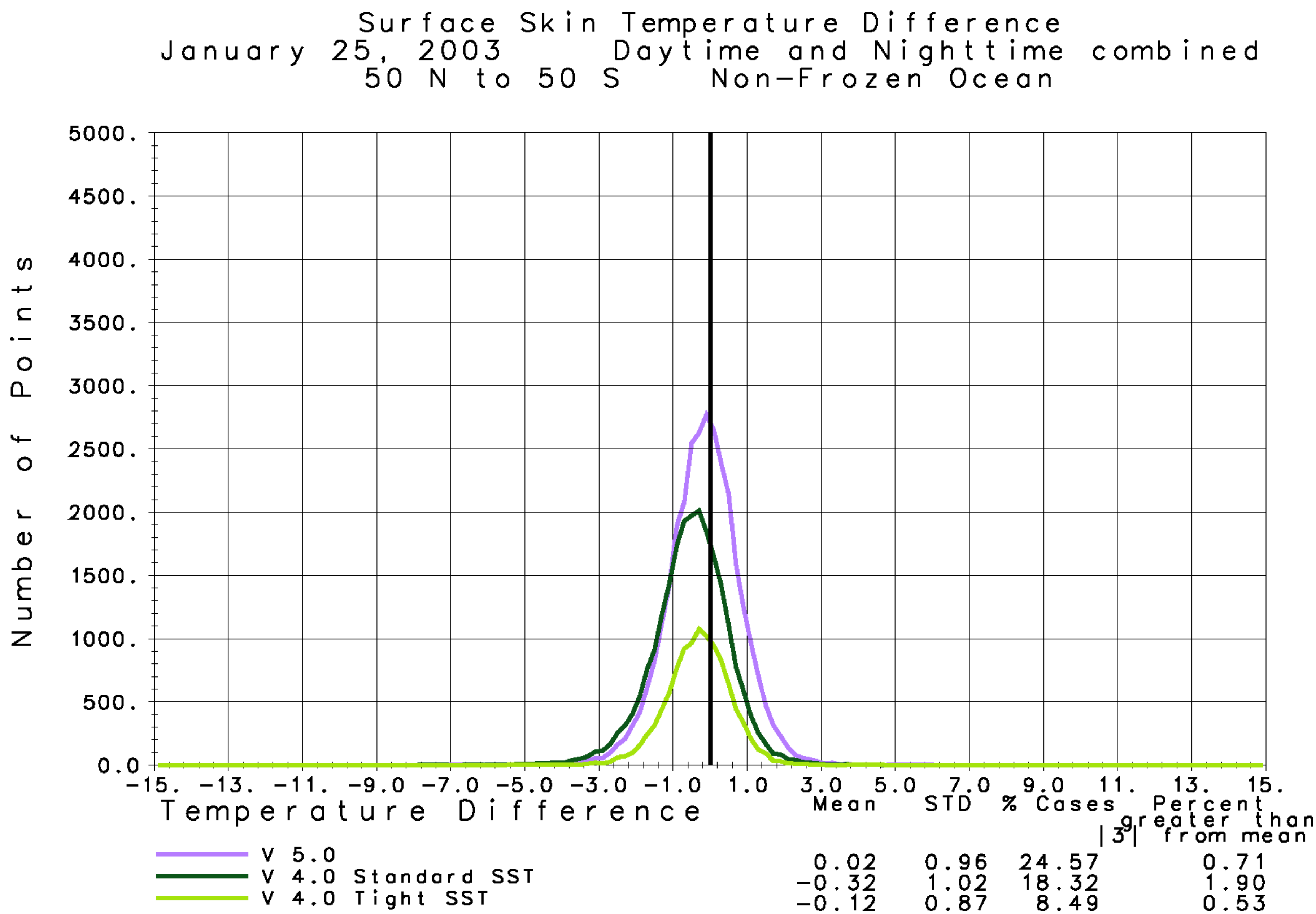
$\delta T(p) >$ threshold for n (currently = 3) consecutive layers

Temperature profile statistics include errors of T(p) down to $p = p_g$

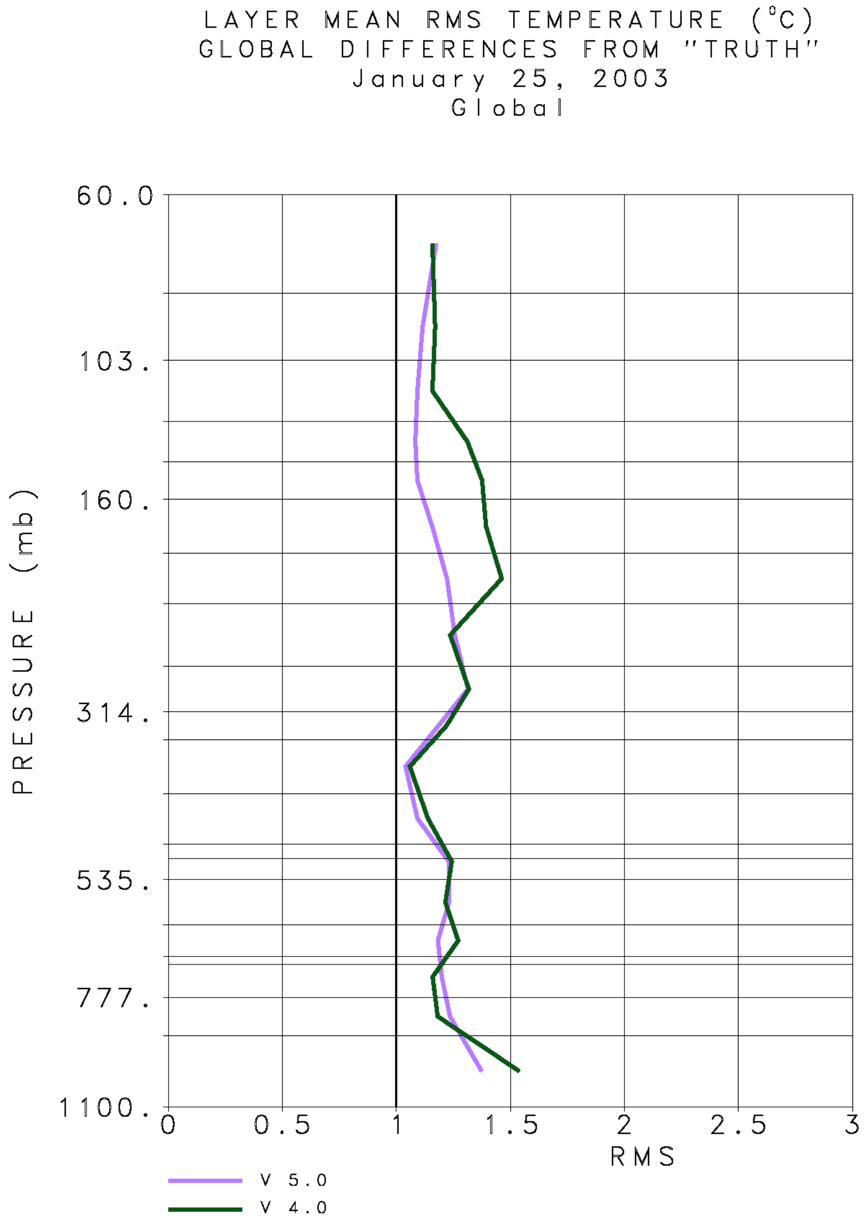
Sea surface temperature SST

Flag SST as good if $\delta SST <$ threshold

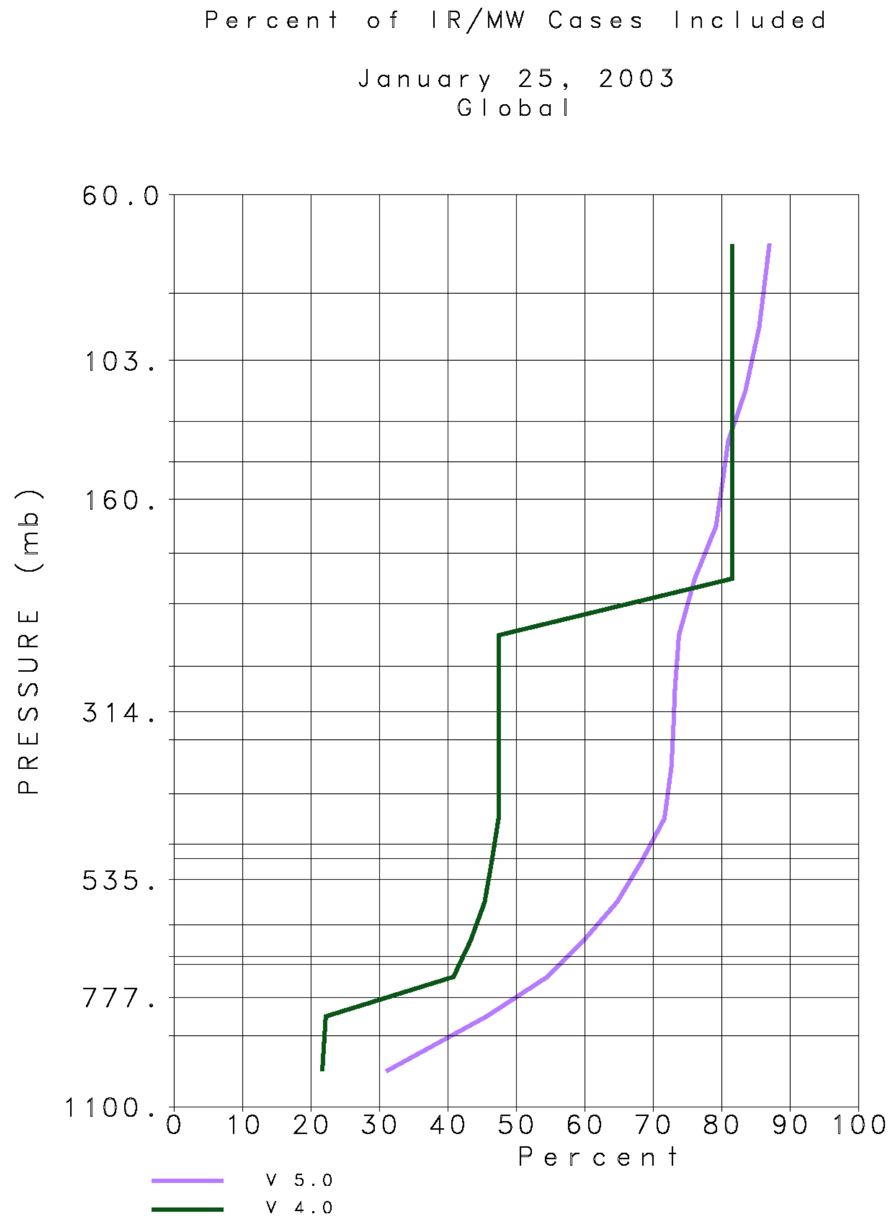

Surface Skin Temperature (K)
Retrieved minus ECMWF
January 25, 2003
(a)
All IR SST Errors
-9.50 -6.50 -3.50 -0.50 1.50 4.50 7.50 10.50
GLOBAL MEAN= -2.83 STANDARD DEV= 7.94
(b)
Predicted SST Errors
0 1 2 3 4 5 6 7 8 9
GLOBAL MEAN= 2.60 STANDARD DEV= 1.94
(c)
Error when Predictor le 1.0
-9.50 -6.50 -3.50 -0.50 1.50 4.50 7.50 10.50
GLOBAL MEAN= 0.08 STANDARD DEV= 0.91
(d)
Predicted SST Error minus Absolute value SST Error
-9.50 -6.50 -3.50 -0.50 1.50 4.50 7.50 10.50
GLOBAL MEAN= -1.49 STD= 6.38 CORR= 0.61
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180
120 W
60 W
0
60 E
120 E
180



Surface Skin Temperature Difference
January 25, 2003 Daytime and Nighttime combined
50 N to 50 S Non-Frozen Ocean
Number of Points
5000.
4500.
4000.
3500.
3000.
2500.
2000.
1500.
1000.
500.
0.0
-15. -13. -11. -9.0 -7.0 -5.0 -3.0 -1.0 1.0 3.0 5.0 7.0 9.0 11. 13. 15.
Temperature Difference
Mean STD % Cases Percent greater than |3| from mean
V 5.0 0.02 0.96 24.57 0.71
V 4.0 Standard SST -0.32 1.02 18.32 1.90
V 4.0 Tight SST -0.12 0.87 8.49 0.53

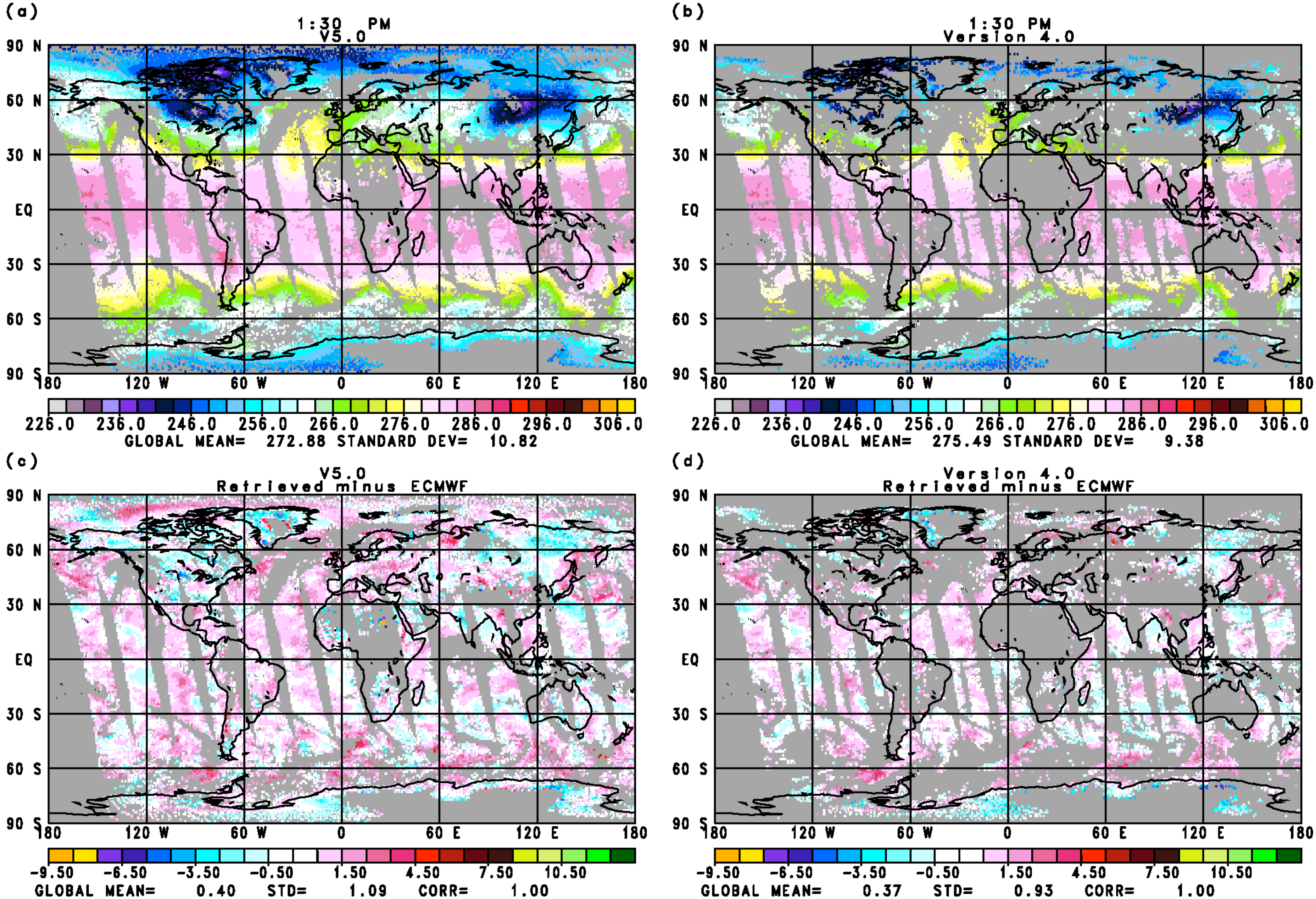


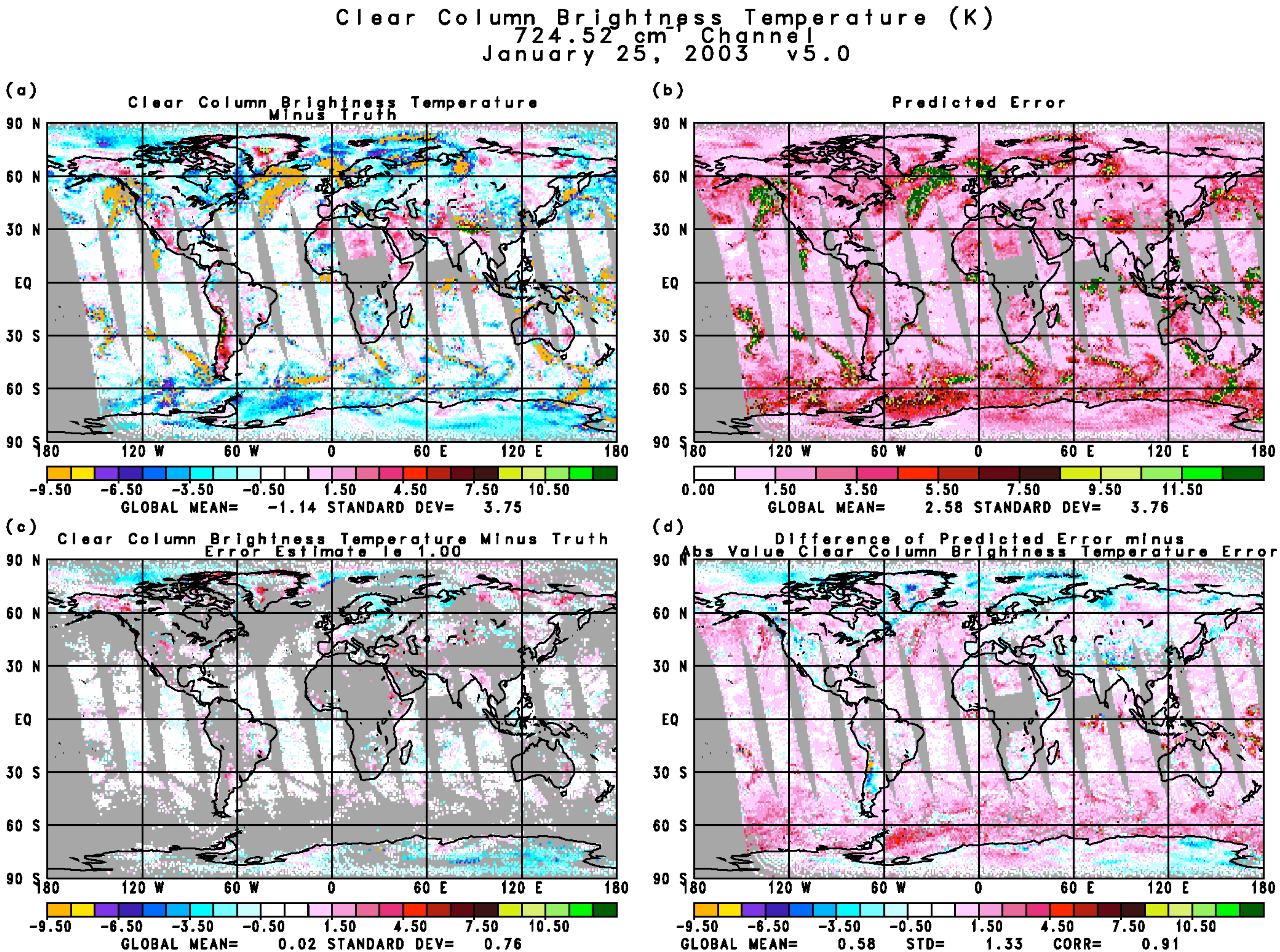
LAYER MEAN RMS TEMPERATURE (°C)
GLOBAL DIFFERENCES FROM "TRUTH"
January 25, 2003
Global
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0
0.5
1
1.5
2
2.5
3
RMS
V 5.0
V 4.0

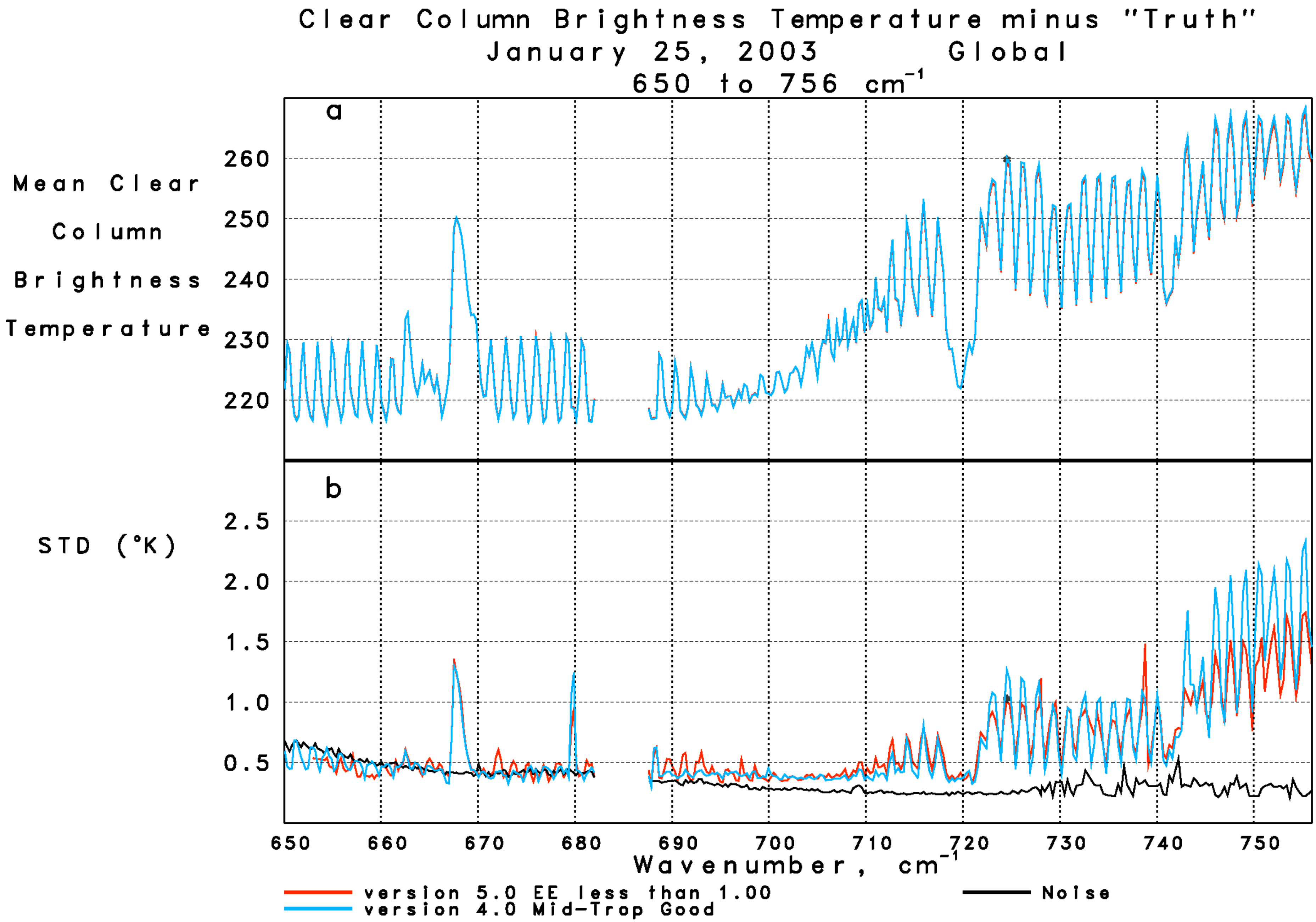


Percent of IR/MW Cases Included
January 25, 2003
Global
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0
10
20
30
40
50
60
70
80
90
100
Percent
V 5.0
V 4.0

700 mb TEMPERATURE (K)
January 25, 2003




Clear Column Brightness Temperature (K)
724.52 cm-1 Channel
January 25, 2003 v5.0
(a)
Clear Column Brightness Temperature
Minus Truth
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180
120 W
60 W
0
60 E
120 E
180
-9.50
-6.50
-3.50
-0.50
1.50
4.50
7.50
10.50
GLOBAL MEAN= -1.14 STANDARD DEV= 3.75
(b)
Predicted Error
0.00
1.50
3.50
5.50
7.50
9.50
11.50
GLOBAL MEAN= 2.58 STANDARD DEV= 3.76
(c)
Clear Column Brightness Temperature Minus Truth
Error Estimate le 1.00
GLOBAL MEAN= 0.02 STANDARD DEV= 0.76
(d)
Difference of Predicted Error minus
Abs Value Clear Column Brightness Temperature Error
GLOBAL MEAN= 0.58 STD= 1.33 CORR= 0.91


Clear Column Brightness Temperature minus "Truth"
January 25, 2003 Global
650 to 756 cm-1
a
b
Mean Clear
Column
Brightness
Temperature
260
250
240
230
220
STD (°K)
2.5
2.0
1.5
1.0
0.5
650
660
670
680
690
700
710
720
730
740
750
Wavenumber, cm-1
version 5.0 EE less than 1.00
version 4.0 Mid-Trop Good
Noise

AIRS ONLY RETRIEVAL SYSTEM (AO)

Retrieval Steps

1 Cloudy regression produces X^1 (AMSU retrieval produces X^1 in AIRS/AMSU system

2 $\hat{R}_i^1$ computed using X^1

3 Generate X^{reg} using $\hat{R}_i^1$, $X^{reg} = X^2$

4 $\hat{R}_i^2$ computed using X^2

5 Physical retrieval gives X^3

Uses $\hat{R}_i^2$, starts with X^2

6 $\hat{R}_i^3$ computed using X^3

7 Physical retrieval - uses $\hat{R}_i^3$, gives solution X^4

Steps 2-7 are almost identical to AIRS/AMSU retrieval system

AMSU channels 1, 2, and 15 are not used in AO water vapor retrieval

8 Apply quality control

Analogous to QC in AIRS/AMSU retrieval system but does not use 3 AMSU based tests

13 terms instead of 16 terms

OVERVIEW OF AIRS CLOUD CLEARING PROCEDURE

Uses radiances in 9 fields of view R_{ij} channel i, FOV j within AMSU A FOR

Allows for up to 8 cloud formations

$\bar{R}_i$ = average radiance over 9 FOV's

$$\hat{R}_i^n = \bar{R}_i + \sum_{j=1}^{9} \eta_j^n \left(R_{i,j} - \bar{R}_i\right) = \bar{R}_j + \sum_{j=1}^{9} \eta_j^n \Delta R_{i,j}$$

9 values of η_j determine $\hat{R}_i$ for all channels

We compute expected values of $R_{i,CLR}^n$ from a state X^n to obtain η^n

$$\eta_j^n = \left(\Delta R' N^{-1} \Delta R\right)^{-1} \Delta R' N^{-1} \Delta R_{CLR}^n$$

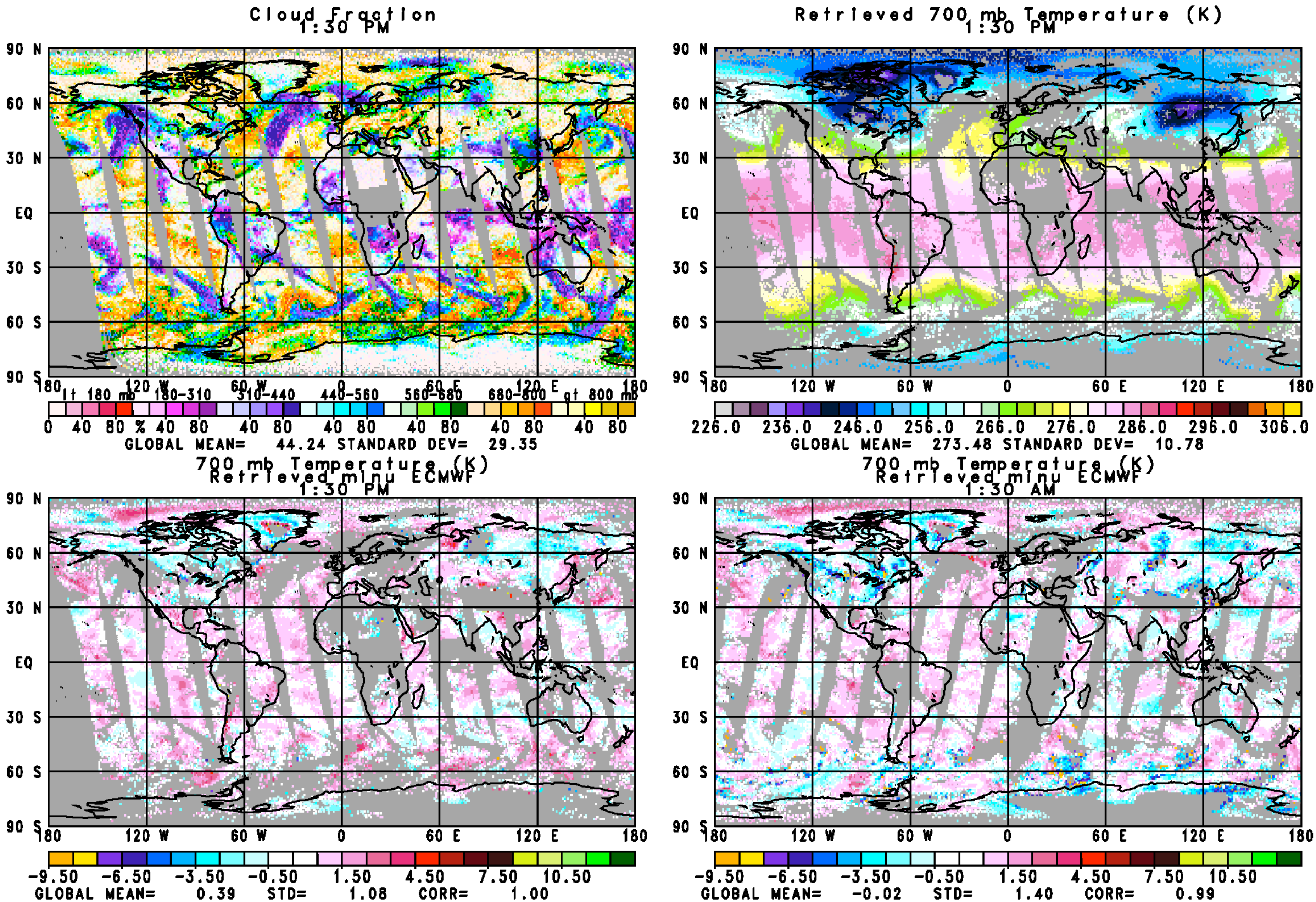
$\Delta R_{CLR,i}^n = R_{i,CLR}^n - \bar{R}$ $R_{i,CLR}^n$ computed from surface and atmospheric state X^n

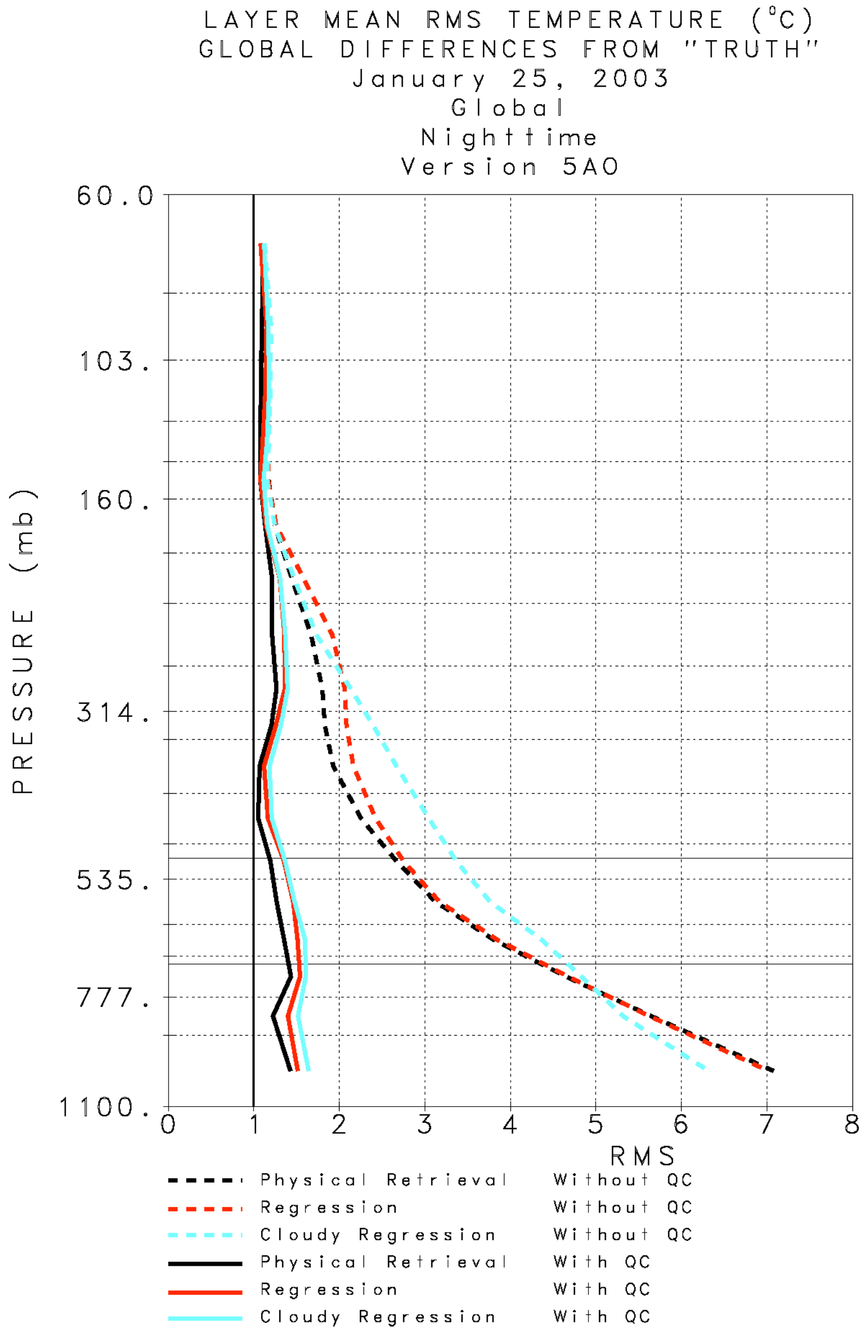
N = channel noise covariance

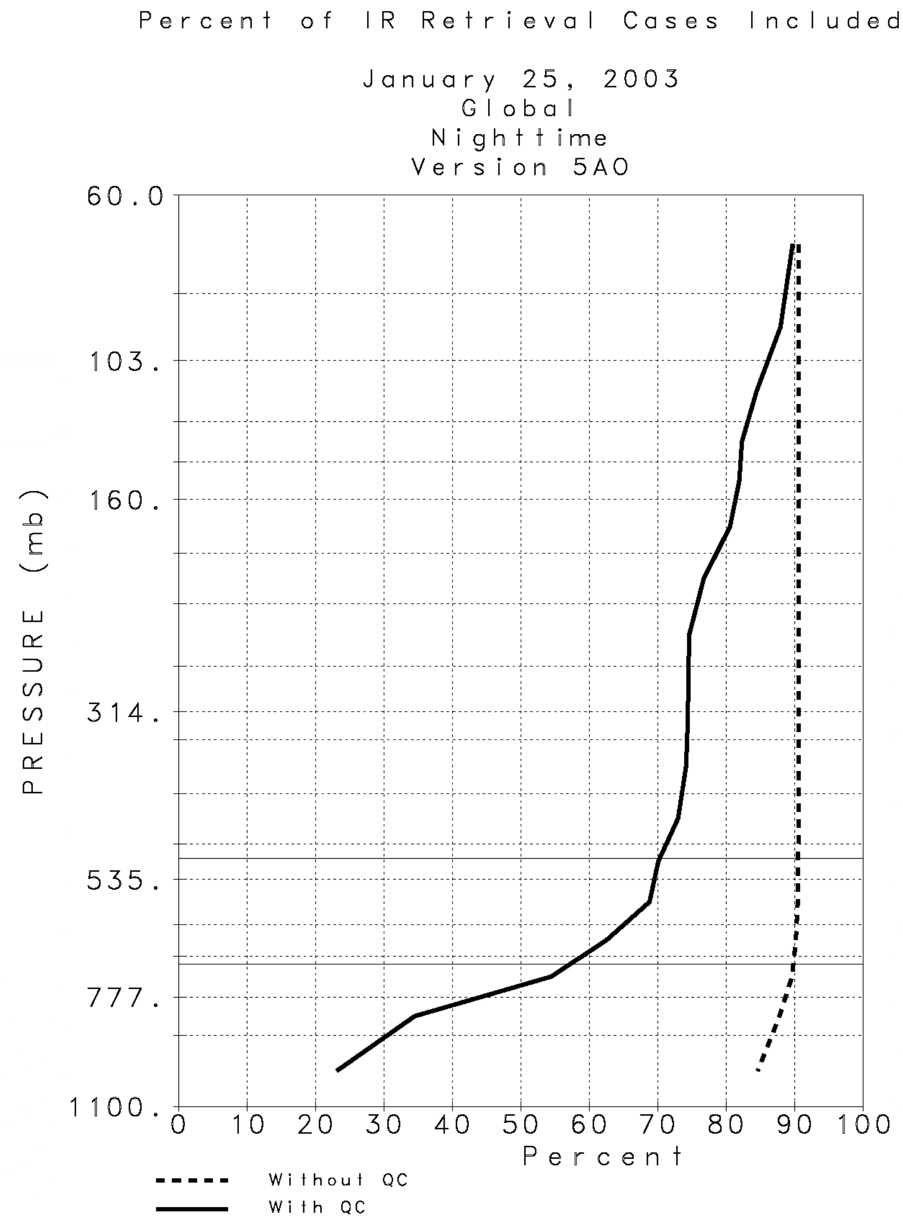
$R_{i,CLR}$ should in principle be an unbiased state

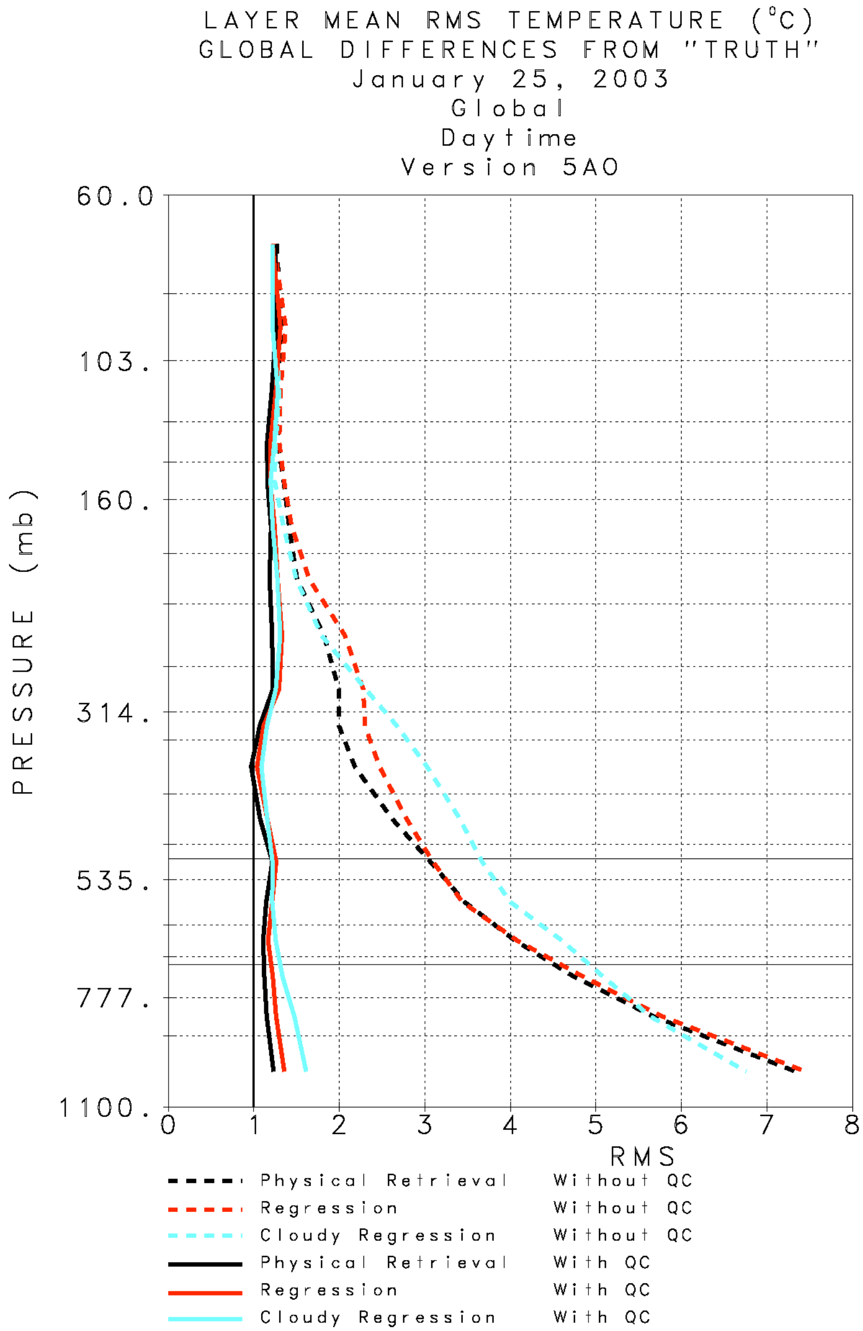
Larger biases may result when X^1 comes from cloudy regression than AMSU retrieval

January 25, 2003
Version 5 AIRS Only

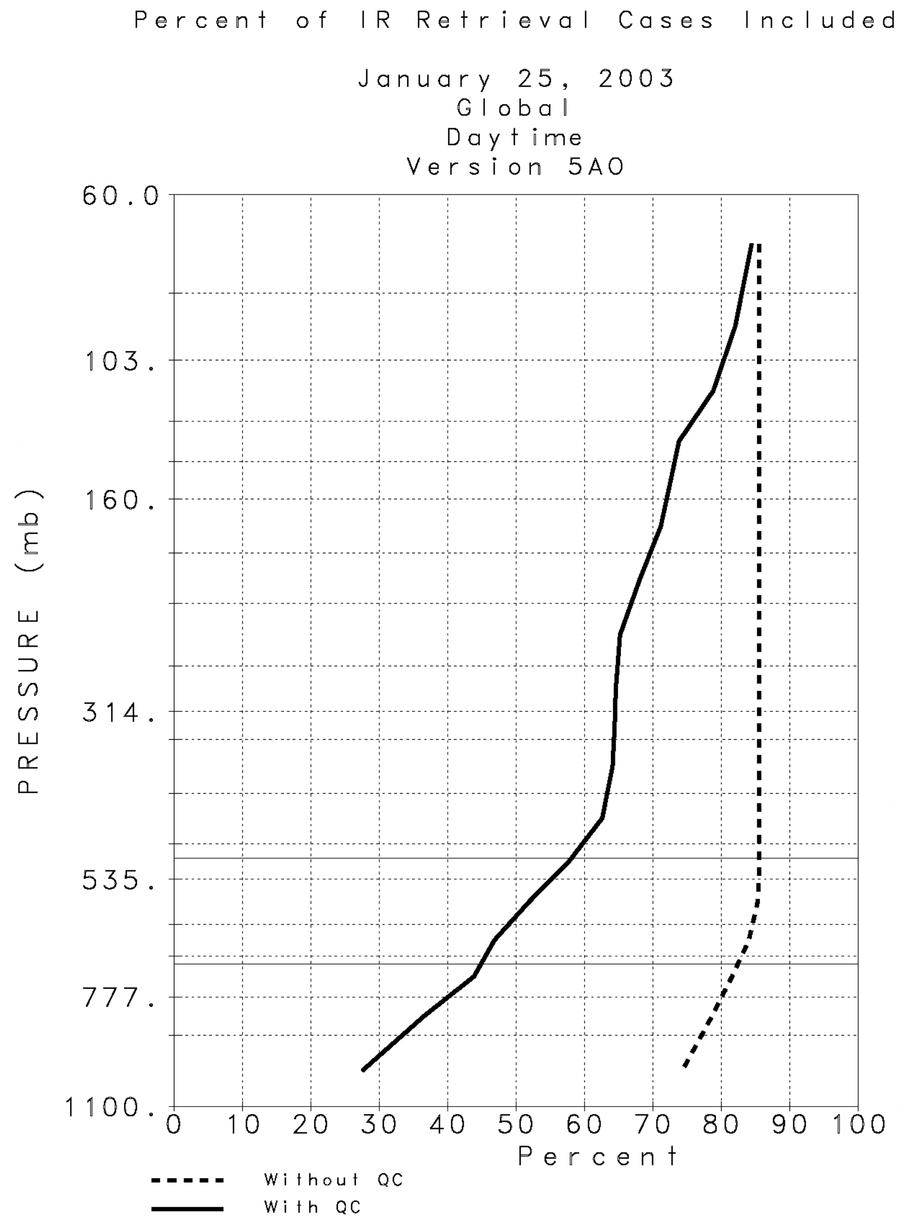



LAYER MEAN RMS TEMPERATURE (°C)
GLOBAL DIFFERENCES FROM "TRUTH"
January 25, 2003
Global
Nighttime
Version 5A0
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0 1 2 3 4 5 6 7 8
RMS
Physical Retrieval Without QC
Regression Without QC
Cloudy Regression Without QC
Physical Retrieval With QC
Regression With QC
Cloudy Regression With QC

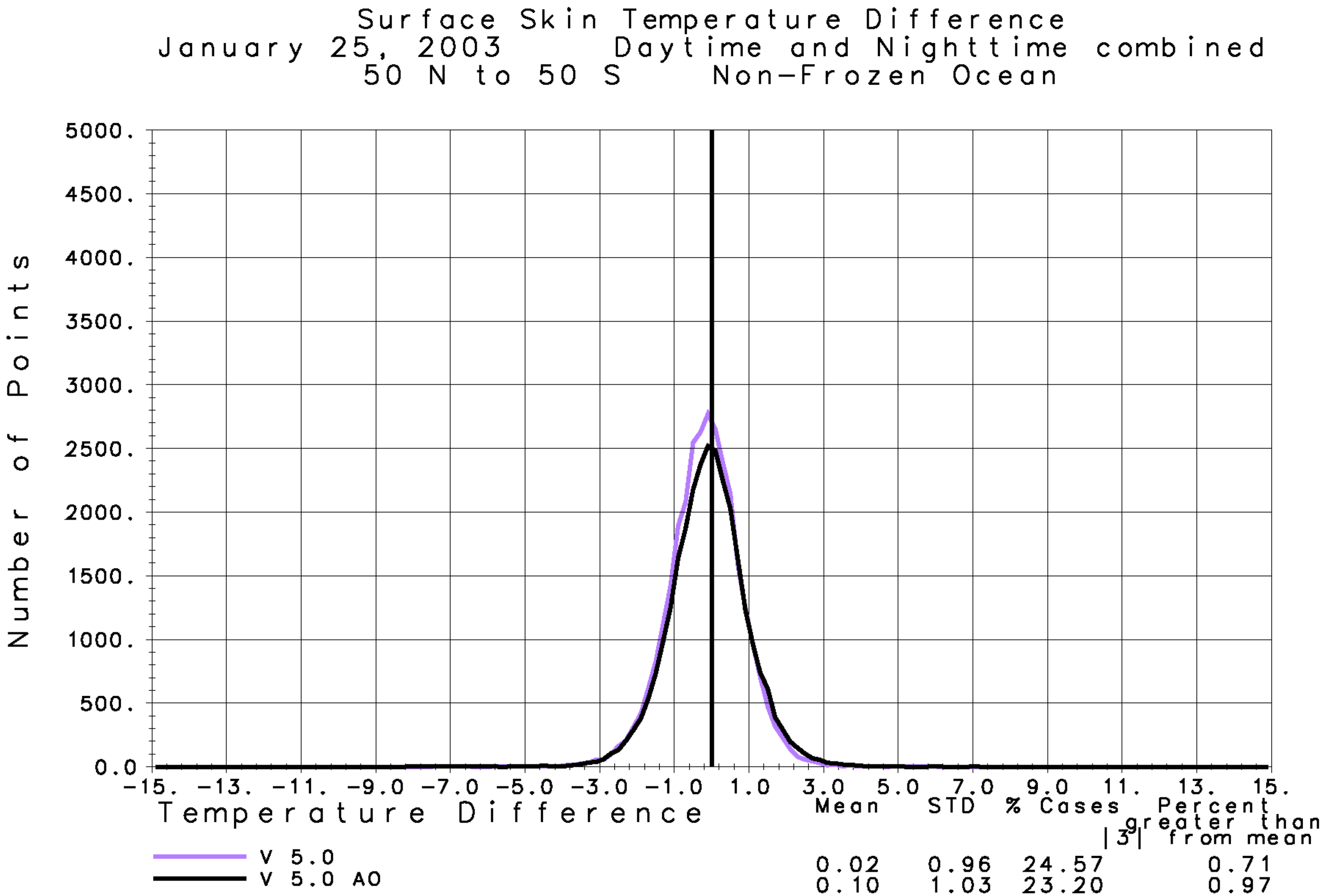

Percent of IR Retrieval Cases Included
January 25, 2003
Global
Nighttime
Version 5A0
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0 10 20 30 40 50 60 70 80 90 100
Percent
Without QC
With QC



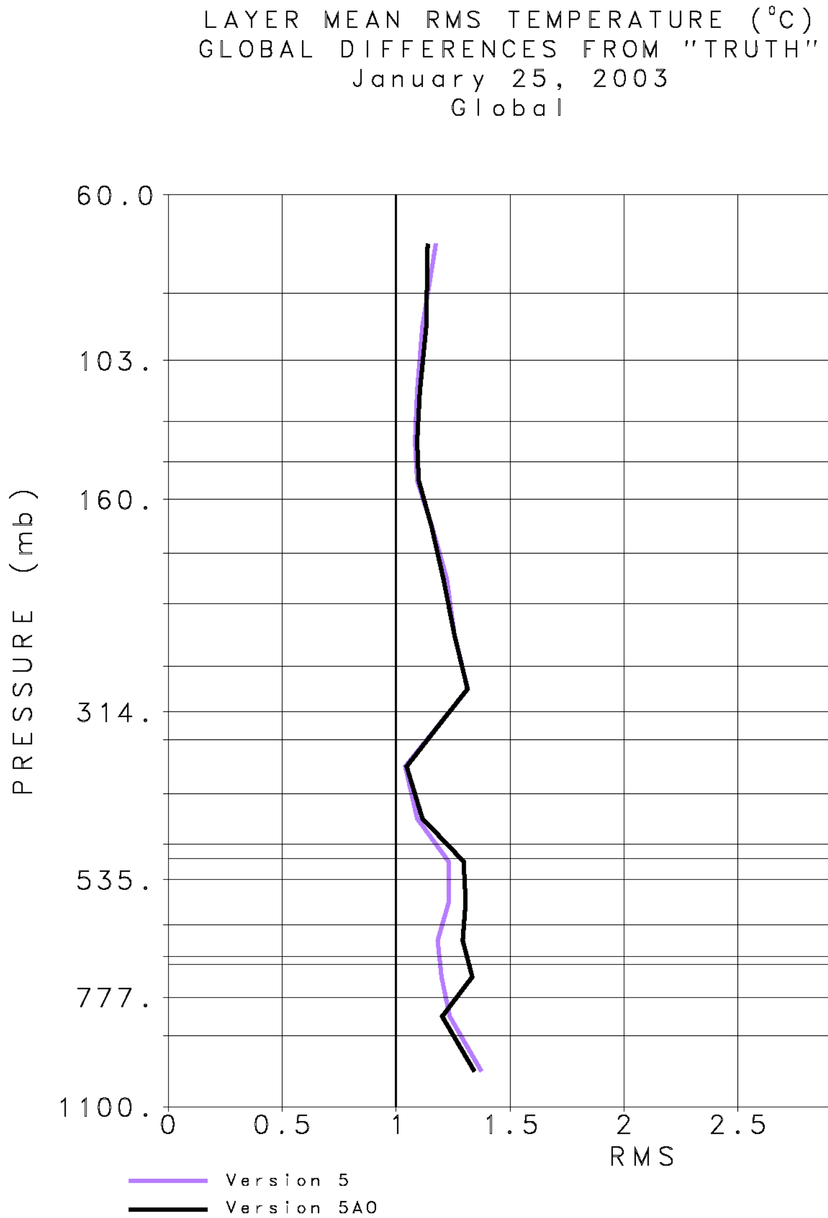
LAYER MEAN RMS TEMPERATURE (°C)
GLOBAL DIFFERENCES FROM "TRUTH"
January 25, 2003
Global
Daytime
Version 5A0
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0 1 2 3 4 5 6 7 8
RMS
Physical Retrieval Without QC
Regression Without QC
Cloudy Regression Without QC
Physical Retrieval With QC
Regression With QC
Cloudy Regression With QC

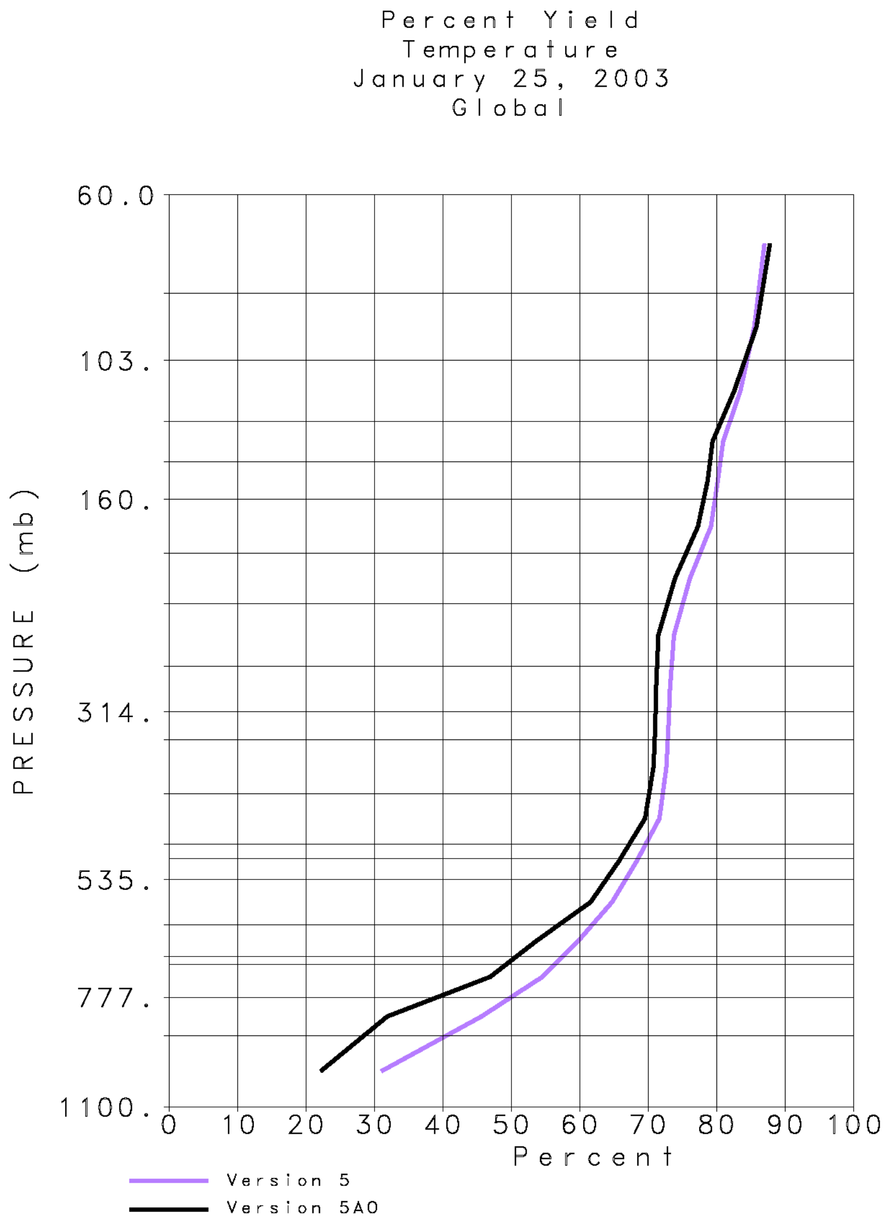


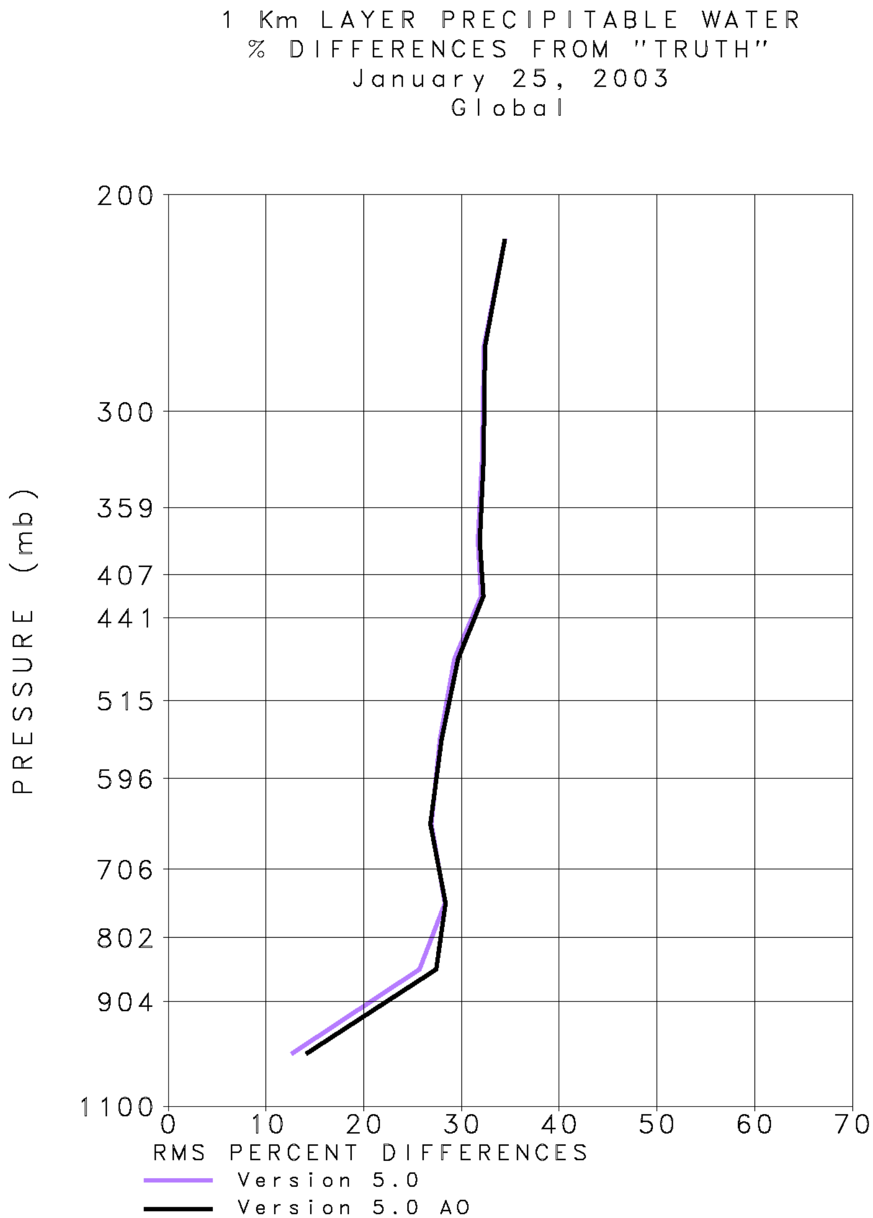
Percent of IR Retrieval Cases Included
January 25, 2003
Global
Daytime
Version 5A0
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0 10 20 30 40 50 60 70 80 90 100
Percent
Without QC
With QC



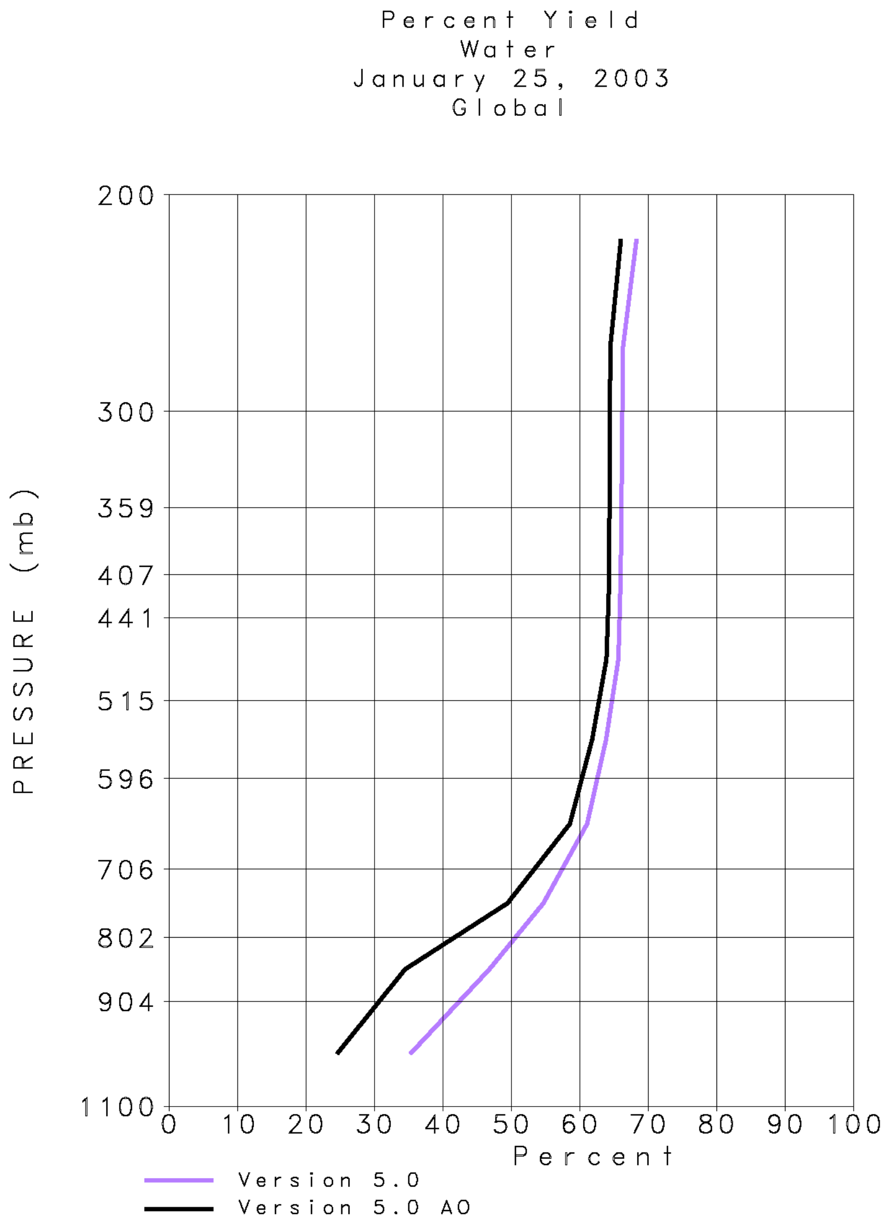
Surface Skin Temperature Difference
January 25, 2003 Daytime and Nighttime combined
50 N to 50 S Non-Frozen Ocean
Number of Points
5000.
4500.
4000.
3500.
3000.
2500.
2000.
1500.
1000.
500.
0.0
-15. -13. -11. -9.0 -7.0 -5.0 -3.0 -1.0 1.0 3.0 5.0 7.0 9.0 11. 13. 15.
Temperature Difference
V 5.0
V 5.0 AO
Mean STD % Cases Percent greater than |3| from mean
0.02 0.96 24.57 0.71
0.10 1.03 23.20 0.97


LAYER MEAN RMS TEMPERATURE (°C)
GLOBAL DIFFERENCES FROM "TRUTH"
January 25, 2003
Global
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0
0.5
1
1.5
2
2.5
3
RMS
Version 5
Version 5AO


Percent Yield
Temperature
January 25, 2003
Global
PRESSURE (mb)
60.0
103.
160.
314.
535.
777.
1100.
0
10
20
30
40
50
60
70
80
90
100
Percent
Version 5
Version 5AO



1 Km LAYER PRECIPITABLE WATER
% DIFFERENCES FROM "TRUTH"
January 25, 2003
Global
PRESSURE (mb)
200
300
359
407
441
515
596
706
802
904
1100
0
10
20
30
40
50
60
70
RMS PERCENT DIFFERENCES
Version 5.0
Version 5.0 AO



Percent Yield
Water
January 25, 2003
Global
PRESSURE (mb)
200
300
359
407
441
515
596
706
802
904
1100
0
10
20
30
40
50
60
70
80
90
100
Percent
Version 5.0
Version 5.0 AO

SUMMARY

Quality controlled Version 5.0 retrievals are significantly better than Version 4.0

Accuracy and spatial coverage

Uses primarily shortwave channels for temperature and surface retrievals

Case by case error estimates are very accurate

Used directly for quality control

Enhance utility of products for both weather and climate applications

Allows for use of AIRS only cloud clearing system

AIRS only backup system performs very well

Demonstrates importance of spectral channels between 2350 cm^{-1} and 2400 cm^{-1} with low noise